

## DEVICE OF PROTECTION AGAINST A POLARITY REVERSAL

### PRIORITY CLAIM

[1] This application claims priority from French patent application No. 03/04144, filed April 3, 2003, which is incorporated herein by reference.

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### FIELD OF THE INVENTION

[2] The present invention relates generally to the protection of electronic circuits against a transient polarity reversal of a D.C. supply voltage. The present invention more specifically applies to the protection of circuits for controlling loads supplied by a D.C. battery, for example, in the automobile field.

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### BACKGROUND OF THE INVENTION

[3] FIG. 1 schematically shows a conventional example of a circuit **1** for controlling a load **2** (Q) supplied by a battery **3**.

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[4] Control circuit **1** comprises a switch **11** (generally a MOS transistor) between a D.C. voltage (Vbat) terminal **12** and a terminal **13** of connection of load **2**, the other terminal of the load being connected (generally directly) to ground and more generally to the other voltage (terminal **32**) of the D.C. power supply than that to which terminal **12** is connected. Circuit **1** generally is an integrated circuit further comprising a terminal **14** of connection to ground and input-output terminals of data exchange (control signals, states, etc.) with a microcontroller **4** ( $\mu$ C). In the example shown, four terminals **15** to **18** of circuit **1**, among which at least one input terminal of a (logic) turn-on control signal of switch **11**, are provided.

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[5] A switch **5** symbolizes a general switch of the electric circuit, for example, actuated by the ignition key of a vehicle. Switch **5** connects positive terminal **31** of battery **3** to terminal **12**.

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[6] Microcontroller **4** is generally supplied by a voltage regulator **6** (VR) receiving, via switch **5** and a diode **61** having its anode connected to the power switch, the battery voltage, and providing a regulated voltage to microcontroller **4**.

[7] Several electric protection elements further equip circuit **1** and its connections.

[8] A first protection element is formed of a zener diode **19**, internal to circuit **1**, connecting terminals **12** and **14**, the anode of diode **19** being connected to terminal **14**. Diode **19** aims at protecting the portion of circuit **1** comprising the control elements of switch **11** by limiting the voltage of terminal **12**.

[9] A second element is formed of a diode **7** connecting terminal **14** to terminal **32**, and thus to the ground or negative terminal of battery **3**, the anode of diode **7** being connected to terminal **14**. The function of diode **7** is to prevent a battery short-circuit in case of a polarity reversal. Diode **7** is on in normal operation and ensures the ground connection of circuit **1**. It is blocked in case of a polarity reversal of the battery and then prevents diode **19** (in the on state) from connecting terminals **32** and **31**, which would be the case if terminal **14** was directly connected to terminal **32**.

[10] Diode **7** may be replaced with a resistor that must then be of small value to avoid a significant voltage drop in normal operation. Such a small value however generates a significant dissipation in case of a polarity reversal of the battery.

[11] Diode **7**, which may be common to several circuits **1**, independently from their consumption, and which generates an approximately constant voltage drop on the order of 0.6 volt, is thus conventionally preferred.

[12] Microcontroller **4** is generally protected against a polarity reversal by diode **61**.

[13] Ground terminal **41** of the microcontroller must generally be directly connected to terminal **32**. This, to enable it reading, without any voltage offset, data from sensors (not shown) directly connected to the battery "minus" **32**.

[14] A disadvantage of diode **7** is that it does not provide a protection of circuit **1** and of microcontroller **4** in case of transient negative pulses on supply terminal **12** (or **31**). In the example of application to automobile, transient pulses correspond to normalized transient disturbances (ISO standard T/R 7637/1) of the battery voltage, of variable power. More generally, such transient pulses may be due, for example, to switchings of loads connected to the D.C. power supply.

[15] Upon positive transient pulses on terminal **12**, diode **7** remains on. Zener diode **19** then behaves as a voltage limiter and protects the control elements of switch **11**.

[16] However, upon negative transient pulses on terminal **12**, diode **7** blocks. The internal ground (terminal **14**) of circuit **1** then becomes strongly negative (with respect to the voltage of terminal **32**). Now, the microcontroller has its ground referenced to terminal **32**. As a result, inputs-outputs **15** to **18** follow the negative voltage of the pulse and draw current from the microcontroller. To overcome this phenomenon, each input-output **15** to **18** of circuit **1** is connected to the microcontroller by a protection resistor **45** to **48**. The resistors must have a strong value (at least on the order of one K $\Omega$ ) to ensure this protection function.

[17] A disadvantage is linked to the presence of resistors **45** to **48** and to their bulk. In particular, the miniaturization objectives result in integrating series interfaces in the packages containing circuits **1** to limit connections to the microcontroller. The connections are then preferentially limited to a number of three (a clock connection, an output connection to the microcontroller, and an input connection from the microcontroller). It being series connections, the data interpretation is preferentially performed by digital words.

[18] The presence of the protection resistors on the input-output lines poses another problem, particularly present for series communications, than that of the resistor size. Indeed, the resistors take part in RC cells (with the input or output capacitances, be they or not stray capacitances) that introduce a non-negligible delay in the data transmission between the microcontroller and the load control circuit(s).

[19] In particular, in the application to the automobile field, the required response times are of at least one microsecond, which is incompatible with the use of series resistors on the order of one K $\Omega$  or more.

#### SUMMARY OF THE INVENTION

[20] An embodiment of the present invention provides protection against polarity reversals that overcomes the disadvantages of known devices. In particular, an embodiment of the

present invention protects against transient reversals while minimizing the value of the resistors of access to the microcontroller, or even eliminating these resistors.

**[21]** An embodiment of the present invention also provides a solution that is compatible with the system miniaturization.

5 **[22]** An embodiment of the present invention provides an integrable solution.

**[23]** An embodiment of the present invention provides a device for protecting a circuit to be protected against a polarity reversal of a connection to a D.C. power supply, comprising:

10 a controllable switch interposed on said connection between a first terminal of application of a first voltage of said D.C. power supply and a first terminal of said circuit; and

first means for turning-off with a delay the switch in the presence of a reverse polarity.

15 **[24]** According to an embodiment of the present invention, said delay is chosen to be greater than the maximum expected duration of transient polarity reversals.

**[25]** According to an embodiment of the present invention, the protection device comprises second means for turning on the switch with a delay shorter than the turn-off delay, when the polarity is normal.

20 **[26]** According to an embodiment of the present invention, said first terminal of the circuit to be protected is a ground connection terminal.

**[27]** According to an embodiment of the present invention, said first means are formed of a microcontroller having an output controlling, directly or via a selective delay element, said switch.

25 **[28]** According to an embodiment of the present invention, said switch is a MOS transistor, preferably with an N channel.

[29] According to an embodiment of the present invention, said first means are formed of a first resistor connecting the transistor gate to said first terminal of the circuit to be protected.

5 [30] According to an embodiment of the present invention, a second resistor in series with a diode connects a terminal of the device connected to a second voltage of the D.C. power supply.

[31] According to an embodiment of the present invention, a zener diode is connected in parallel with the first resistor.

10 [32] Features and advantages of the present invention will be discussed in detail in the following non-limiting description of specific embodiments in connection with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[33] FIG. 1, illustrates a prior-art circuit for controlling a load supplied by a battery;  
FIG. 2 shows, in the form of functional blocks, an embodiment of a protection device according to the present invention;  
15 FIG. 3 shows an embodiment of the present invention used in the example of application of FIG. 1; and  
FIG. 4 shows an embodiment of the protection element of the present invention.

#### DETAILED DESCRIPTION

[34] Same elements have been designated with same references in the different drawings. For clarity, only those elements necessary to the understanding of the present  
20 invention have been shown in the drawings and will be described hereafter. In particular, the controlled loads as well as the processes of control by the microcontroller have not been detailed because they may be conventional. Further, embodiments of the present invention will be more specifically described in relation with an example of application to the automobile field, but all described herein applies, unless otherwise specified, to any  
25 load supply by a D.C. voltage likely to undergo transient or lasting polarity reversals and posing analog problems.

[35] An embodiment of the present invention provides, between the terminal of ground connection (or more generally of connection to one of the D.C. supply voltages) of a load control circuit and the ground, a specific protection element. This element has the feature of being on in normal operation, of being off in case of a lasting polarity reversal, and of remaining on during transient (temporary) polarity reversals.

[36] FIG. 2 shows a first embodiment of a ground connection protection device according to the present invention. FIG. 2 comprises the elements of a conventional assembly of the type shown in FIG. 1. For simplification, the representation of FIG. 2 is partial, only protection device 8 according to an embodiment of the present invention, microcontroller 4, and a portion of control circuit 1 are- been shown.

[37] According to this embodiment, device 8 is functionally formed of a normally-on switch 81, connecting terminal 14 of circuit 1 to ground 32, and of a delay element 82 ( $\tau$ ) delaying the turning-off of switch 81 after a detection of a polarity reversal of the D.C. supply voltage. The detection of a polarity reversal may be performed by microcontroller 4 if said microcontroller has a power supply insensitive to polarity reversals. An output 49 of the microcontroller providing the state (or the direction) of the polarity is then connected to the input of delay element 82 having its output controlling, at least to turn it off, switch 81.

[38] The delay introduced by element 82 is a function of the maximum durations expected for transient disturbances and is thus adjustable to predetermined values appropriate for particular applications. The delay occurs at the turning-off, which enables not taking into account a temporary reversal if the polarity becomes normal again before expiry of the delay set by delay element 82. Preferably, the delay only occurs at the turning-off of switch 81. For example, delay element 82 lets through with no delay a low state (0) indicative of a normal polarity to immediately turn on switch 81, and delays the propagation of a high state (1) indicative of a polarity reversal. According to an alternative implementation, the delay of element 82 is calculated by the microcontroller that then directly controls switch 81.

[39] FIG. 3 shows a second embodiment of a ground connection protection device **8** (GP) according to an embodiment of the present invention. The device connects like that of FIG. 2, except that it itself detects the polarity reversal and comprises for this purpose a terminal **83** for receiving battery voltage Vbat connected, preferably, to the same point as positive supply terminal **12** of circuit **1**. As an alternative (shown in dotted lines), terminal **83** for receiving the supply voltage is connected upstream of general switch **5**, directly on the positive supply terminal. FIG. 3 thus comprises the elements of FIG. 1, except for diode **7** and resistors **45** to **48**. Device **8** comprises a switch **81** (not shown in FIG. 3) and a means equivalent to delay element **82**.

10 [40] The operation of devices **8** of FIGs. 2 and 3 will be described hereafter.

[41] According to an embodiment of the invention, a major difference between protection device **8** and conventional diode **7** is that element **8** blocks with a delay upon occurrence of a polarity reversal. Thus, the assembly operates as follows.

15 [42] In the presence of a normal supply voltage Vbat (positive between terminals **12** and **32**), switch **81** is on, just as diode **7** was previously forward-biased. Diode **19**, internal to circuit **1**, performs its normal function of control circuit protection for transient pulses.

[43] In this configuration, the voltage drop across conductive element **8** is that of switch **81**. In the most frequent case, the switch **81** will be a MOS transistor. An advantage then is that it minimizes the voltage drop between terminals **14** and **32**. As illustrated in FIG. 3, this may enable connecting the ground of microcontroller **4** upstream of device **8** (and thus on terminal **14**) and thus protecting microcontroller **4** at the same time. Of course, it is not excluded, as an alternative, to keep the conventional ground connection of the microcontroller as illustrated in dotted lines in FIG. 3.

25 [44] In the presence of a transient negative voltage, switch **81** does not turn off (conversely to diode **7** of the conventional assembly) since delay element **82** (or the equivalent element of device **8** of FIG. 3) is sized to introduce a delay greater than the expected maximum delay of transients to be ignored by the system.

[45] In fact, a current **I** (defined based on the maximum transient voltage, generally standardized) flows through diode **19** and through switch **81**. Assuming an impedance **Z**

in the on state of switch **81**, the voltage drop in element **8** is  $Z.I$ . The voltage across the assembly then is limited to  $Z.I + V_f$ , where  $V_f$  designates the voltage across diode **19** (in practice, less than one volt).

5     **[46]** As a result, during such a negative transient, the voltage applied to the terminals of microcontroller **4** connected to input-output terminals 15 to 18 of circuit 1 cannot exceed a magnitude of  $Z.I + V_f$ .

**[47]** Switch **81** is sized to hold the maximum current of the most energetic expected transient pulses.

10    **[48]** An advantage is that resistors **45** to **48** for protecting the microcontroller inputs-outputs may be reduced according to a ratio of at least 100 (in practice, values on the order of  $1\Omega$  or some  $10\Omega$  are enough), or even eliminated. In particular, if the microcontroller ground connection is connected to terminal **14** of the circuit, the voltage applied on the microcontroller inputs-outputs is limited to  $V_f$  (less than one volt). In the example of **FIG. 3**, resistors **41** to **44** have been illustrated in dotted lines in the place of  
15    resistors **45** to **48**.

**[49]** Another advantage is that it is then possible to provide series connections between the microcontroller and circuit(s) **1** protected by the device **8** while allowing a fast response of the system to orders from the microcontroller.

20    **[50]** In the presence of an incidental (lasting) reversal of the supply voltage polarity, switch **81** turns off after time ( $\tau$ ) and the short-circuiting of the power supply by diode **19** internal to circuit **1** is then avoided.

**[51]** It will be ascertained for the breakdown voltage of the device **8** (and switch **81**) to be greater than the maximum reverse voltage that the circuit can see (generally 16 volts in the case of an automobile battery).

25    **[52]** A simple embodiment of device **8** is a MOS transistor controlled in all or nothing (for example, 0 or 5 volts) by microcontroller **4**, which takes on all of the detection. A still simpler control consists of connecting the gate of the MOS transistor directly to the output (for example, 5 volts) of regulator **6**. The turn-off timing then originates from the



regulator's capacity of maintaining its output voltage in the case where its input voltage disappears. This embodiment may be used, for example, for applications where it is not indispensable to precisely control the turn-off delay.

**[53]** FIG. 4 shows a preferred embodiment of device **8** of FIG. 3 according to an

5 embodiment of the present invention (autonomous device integrating the turn-off time constant).

**[54]** According to this embodiment, preferably implemented as an integrated circuit, switch **81** is an N-channel MOS transistor. The drain of transistor **81** is directly connected to a terminal **84** of device **8** intended to be connected to ground connection terminal **14** of circuit **1** to be protected. Its source is directly connected to a terminal **85** of device **8** intended to be directly connected to ground **32** (or to the most negative terminal of the power supply). The gate of transistor **81** is connected, via a first resistor **86** in series with a diode **87**, to detection input terminal **83**. The cathode of diode **87** is directly connected to the gate of transistor **81** while its anode is connected, by resistor **86**, to terminal **83**.

10 The gate of transistor **81** is further connected to terminal **84** by a second resistor **88**, preferably greater than the value of resistor **86**.

**[55]** When a positive voltage is present on terminal **83** (positive supply voltage), diode **87** conducts and transistor **81** is on.

**[56]** In the case of a polarity reversal of voltage  $V_{bat}$ , diode **87** immediately blocks.

20 Transistor **81** however remains on for as long as resistor **88** has not discharged its gate capacitance. If the polarity reversal is transient, the transistor gate has no time to discharge. When the transient disturbance disappears, diode **87** becomes conductive again and transistor **81** is back on. The turning-on of transistor **81** is conditioned by the charge of its gate capacitance through resistor **86**.

25 **[57]** If the polarity reversal carries on, transistor **81** turns off, which prevents the short-circuiting of the power supply.

**[58]** The value of resistor **88** is set according to the gate capacitance of transistor **81** and to the maximum duration of the transient polarity reversals for which the circuit is not

desired to be turned off (for example, to have a time constant on the order of one millisecond).

5 [59] Preferably, a zener diode **89** connects the gate of transistor **81** to terminal **84**, its anode being connected to terminal **84**. The function of this diode is to limit the gate-source voltage of transistor **81** when said transistor is on to the threshold voltage of diode **89** plus the gate-source voltage of transistor **81**. Also, the diode **89** limits the gate-drain voltage of the transistor **81** to the diode's zener voltage during a transient polarity reversal.

10 [60] In the case of the use of an N-channel MOS transistor as a switch **81**, it will be ascertained to connect the bulk to the drain to avoid, by a connection of the bulk to the source, the presence of a parasitic diode that would be forward-biased during polarity reversals.

15 [61] The value of resistor **86** is, preferably, selected to be as small as possible (for example, at least ten times smaller than that of resistor **88**. Resistor **86** may even be omitted if the voltage on terminal **83** does not risk exceeding the avalanche voltage of diode **89**, resistor **86** of which limits its current. Since resistor **86** has a value smaller than that of resistor **88**, the turning-on is faster than the turning-off. This especially enables respecting the required speeds for the starting of circuit **1** (or the restarting after a transient disturbance).

20 [62] Another advantage of device **8** of FIG 4 appears on disappearing of the supply voltage (for example, on turning-off of general switch **5**). Indeed, the turn-off delay of switch **81** with respect to this disappearing of the supply enables carrying off a residual current into load **2**. Such is the case, in particular, if load **2** is at least partially inductive. Conductive switch **81** is used as a free wheel element (provided that switch **11** of circuit **1** also remains on) on turning-off of general switch **5**, conversely to conventional diode **7**  
25 that instantaneously blocks. The occurrence of overvoltages at the level of switch **5** (for example, the ignition key of a vehicle) likely to generate an arc thereacross is thus avoided.

[63] The protection device **8** may be part of a discrete circuit or integrated circuit that is located in a system, such as the electrical system of an automobile.

**[64]** Of course, the present invention is likely to have various alterations, modifications, and improvements. In particular, a protection device may be provided on the connection to the most positive voltage. In this case, a P-channel MOS transistor maybe provided on the positive supply side.

5     **[65]** Further, the sizing of the different components of the device **8** is within the abilities of those skilled in the art based on the functional indications given hereabove.

**[66]** Finally, although the above embodiments of the present invention have been described in relation with a single control circuit and a single protection device, a same protection device may be shared by several different charge control circuits.

10    **[67]** Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the spirit and the scope of the present invention. Accordingly, the foregoing description is by way of example only and is not intended to be limiting.